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# All silica photonic bandgap fiber

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**Abstract:** We demonstrate theoretically, for the first time to our knowledge, an all silica photonic bandgap fiber. The fiber has a pure silica core and a low-index contrast photonic crystal cladding comprised of raised-index rods.

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## 1. Introduction

The concept of photonic bandgap (PBG) guidance in optical fibers was first demonstrated in 1995 and has since then attracted a considerable amount of attention [1]. Photonic bandgap (PBG) fibers have a cladding region comprised of a periodic microstructure, and a core region that is created by introducing a defect in the cladding structure. Most examples of PBG fibers use air holes in a silica background to define a low-index photonic crystal. In this paper, we propose a new, all silica PBG fiber with a photonic crystal of high-index rods, obtained using present day silica doping techniques.

## 2. Design and theoretical results

Fig. 1 shows the design of the all silica PBG-fiber used in this analysis. The cladding structure is realized using a close-packed arrangement of high-index rods, and a low-index core is created by the omission of a single rod. Birks et al. have previously demonstrated the silica and air material system may provide out-of-plane PBGs for index contrasts that are significantly smaller than required for in-plane 2D photonic crystals [1]. Birks et al. concluded, however, that rod-type of photonic crystal claddings were not feasible (as isolated silica rods may not be supported in a stable manner). Bise et al. recently demonstrated that rod-type PBG fibers may indeed be realized by filling the voids in a holey photonic crystal fiber with a high-index liquid [2]. We have extended the work on rod-type PBG fibers and found that even for very low-index contrasts (even less than a percentage), full 2D out-of-plane PBGs may be realized. This result has many exciting prospects as it provides means to completely eliminate the use of air holes in PBG fibers.

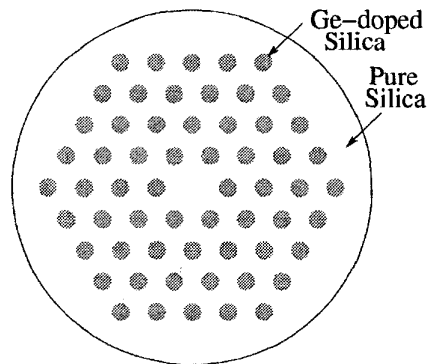


Fig. 1. All silica PBG fiber.

Fig. 2 shows the PBGs exhibited by the cladding structure and the mode index of a defect mode confined to the low-index core. The PBG boundaries are plotted against normalized wavelength,  $\lambda/\Lambda$ , for hole diameter of  $0.4\Lambda$  and refractive index contrast of 1.45:1.47 (index contrasts that may be realized using Ge-doping). It is important to notice that the core mode index is positioned below the refractive index of *any* material that constitute the fiber – a

characteristic only found for PBG fibers. As shown in Fig. 3, the mode is well confined to the core defect and has a Gaussian-like field distribution. Also it is found that the core mode is only confined in a limited spectral range (in this case from  $\lambda/\Lambda$  of around 0.15 to 0.40) – a further known characteristic of PBG fibers. A difference, however, between the here-presented PBG fiber and the holey PBG fibers is the properties of the cladding modes above the upper PBG edge at short wavelengths. For holey PBG fibers, the cladding structure supports a large number of modes that expand the entire background material. For high-index rods PBG fiber, however, the cladding modes become increasingly confined to the individual cladding rods at short wavelengths.

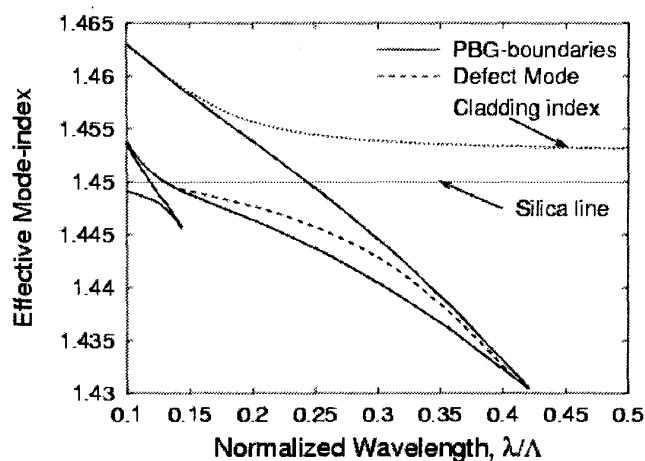


Fig. 2. Index of the defect mode traverses the PBG below the silica line.

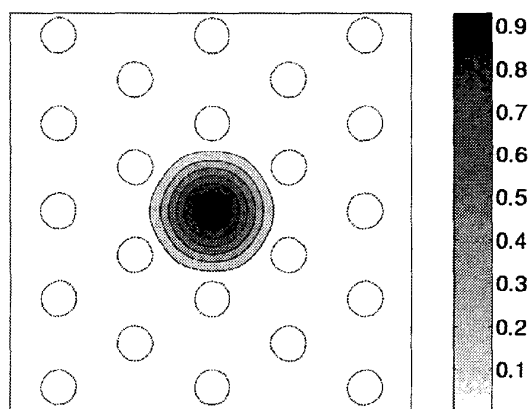


Fig. 3. The fundamental mode of the PBG fiber.

### 3. Conclusion

In this work, we have demonstrated a new type of PBG fiber that may be realized in all silica, solid fiber form. The fiber provides a number of characteristics only found for PBG fibers, such as a defect mode confined to a low-index core and spectral cut-offs at an upper and lower PBG edge. The new fiber may be fabricated using stacking of solid rods – thereby eliminating difficult steps relating to drawing of air holes as previously done for PBG fibers – and should pave the way for increased experimental investigations of this exciting class of optical fibers.

### 4. References

- [1] Birks et al., Elec. Letters 31, 1941 (1995)
- [2] Bise et. al., ThK3, OFC (2002)